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CONSULTING ENGINEERING & PROFESSIONAL SERVICES

REG. NO. 5-9185

Our Project No.
Your Reference No. CA-07406

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CONTRACT REPORT NO. OSQ85-00285

Department of Supply & Services
11C1 Place De Portage
Phase Three
11 Laurier Street
Hull, Quebec
K1A 0S5

Attention: Mr. D. Fraser

Dear Sir:

RE: D-Cracking Study
File No. 15SQ23440-8-9185

Following our May 7, 1986 report, additional information with regard to the literature survey has been requested. Specifically, a critique of each of the 30 papers listed was requested. This letter presents that critique along with a new list of papers as Appendix 'A'.

As an introduction D-Line or D-Cracking, is defined as a defect which becomes apparent at either outside edges or control or saw-cut joints in concrete pavements. The defects are produced by aggregates which absorb sufficient moisture to fracture upon freezing. This fracturing allows further moisture to penetrate and ultimately produce concrete paste and aggregate fractures parallel to the joints or edges along which the moisture was first penetrating. This type of defect is initiated most often in the underside of slabs where saturation of the aggregate particles can be accomplished. This type of failure usually progresses from edges or joints into the concrete mass with time.

MICROMEDIA

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GEOTECHNICAL AND MATERIALS ENGINEERING — ENVIRONMENTAL MATERIALS AND CHEMICAL SCIENCES
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Of primary consideration in selection of coarse aggregates for Portland Cement concrete pavements are those points relating to freeze/thaw durability and the resistance to development of D-Cracking. Pavement properties are related to the critical saturation point of the coarse aggregates, to moisture movement within the concrete section, and to response of aggregates to freeze/thaw cycles upon reaching the level of critical saturation.

It has been found by most of the authors of papers referenced, that the non-durable aggregates are generally sedimentary in nature and of the limestone geological origin.

The results of this literature review have been broken down into five major subjects. These are:

1. D-Cracking, Cause and Prevention, Design and Construction
2. Pavement Performance Related to D-Cracking
3. Aggregates including re-cycled D-Cracked Concrete, Cement and Bases, all relating to D-Cracking of Concrete
4. Pavement Distress, Rehabilitation and Management
5. Testing, ASTM Modified Procedure C666, Pore Size Studies, and the Iowa Pore Index.

In terms of the causes of D-Cracking, eight authors have discussed this subject and all have attributed the cause to the phenomenon discussed above. Specifically, aggregates with specific pore size characteristics take on moisture to the point of critical saturation and upon exposure to freezing conditions, break down ultimately causing concrete paste matrix and concrete section failure. Stark and other authors have reviewed the methods of design to accommodate special base conditions and susceptible aggregates. They

have monitored moisture barriers, sub-base type and condition, shoulders, joints, sealers, and the sub-base moisture related to the concrete performance.

Some conflict exists in the recommendation, particularly with regard to the value of moisture barriers and sub-base drainage systems for control and prevention of D-Cracking in concrete pavement sections. For example, Klieger, Monofore and Teske concluded that road base moisture, whether it be capillary or bulk water, had little ultimate effect on D-Cracking. On the other hand, Stark, Cady and Carrier in their study found that it was absolutely essential to have tile drainage in the shoulders to prevent D-Cracking. On one hand, the level of the moisture was concluded to be insignificant, whether it was capillary or saturated bulk water; and on the other hand, tile drainage which would have eliminated bulk water but not capillary water was concluded mandatory for prevention of D-Cracking.

Further review of the benefits of vapour barriers and in fact of drainage systems beneath either control joints or shoulders is essential to determining potential benefits of such procedures. In terms of pavement performance as a result of D-Cracking, Bukovatz, Crumpton and Worley have documented the relationship of aggregates, particularly the Kansas limestones with regard to pavement performance. These authors all have concluded that sensitive aggregates must be reduced in terms of maximum size to control D-Cracking. Kleiger, Monofore and Teske, as well as the Missouri State Highway Commission and authors Winslow, Lindgren, and Dolch have documented specific gravities, aggregate rating systems related to freeze/thaw studies and durability factors relative to quality of aggregate and the control of D-Cracking. All fifteen papers which have been identified as dealing with quality of aggregates, recycling of aggregates, and treated bases, have concluded

maximum sizes of the coarse aggregate which is of suspect void ratio should be limitied in order to control this cracking phenomenon. Myers and Dubberke have defined pore index as a measuring index relating the voids and voids size of susceptible limestone aggregates. Their rating has defined aggregates which have either low or high ratings as needing no further testing for either acceptance or rejection. Ratings in between these two limits are labelled as suspect and require thorough geological typing and testing to verify susceptibility of each aggregate source and type for potential to cause concrete D-Cracking.

To summarize, the aggregates in terms of pavement performance, it is recommended firstly that susceptible limestone aggregate should be eliminated and failing this they should be crushed to a maximum coarse aggregate size consistent with durability factors and for indices which document potential durability in susceptible environments. These papers also suggest some benefit to the provision of devices to keep moisture from penetrating joints, to control water access to the underside of the slab.

Four papers have been identified as dealing with pavement distress, rehabilitation and management. These authors mainly present case histories of deterioration of various concrete pavement sections by processes of scaling from freeze/thaw distress as well as by distress related to D-Cracking along joints and edges. Havens, in his paper, describes the present condition, history, and state-of-knowledge at the time of pavement design and placement relative to the present state-of-knowledge in his evaluation of D-Cracking phenomenon. A process and procedure for pavement assessment, considering the complications of D-Cracking, have been prepared for Kentucky Highway Systems by Haven and Drake. These procedures ranged from simple visual assessment of pavements to aerial surveys and photography to note staining which is typical in D-cracked concrete.

Finally, testing has been covered by nine different papers in our literature review. These tests have included ASTM Procedure C666, modified to note aggregate elongation, pore size related to maximum particle size, permeability and porosity, and finally the Iowa Pore Index which determines void size and spacing within aggregate particles. All authors reviewed in this literature search conclude that the Iowa Pore Index is a very good method of determining the potential for aggregates to react and for concrete to exhibit D-cracking. In fact, correlation of this test result with field performance has proven excellent. Other tests such as the Critical Dialation by ASTM Procedure 671 has been discovered to be a poor indicator of the potential for aggregate and concrete to exhibit D-Cracking.

All papers reviewed with regard to testing have dealt with testing materials prior to placement of concrete pavements. Summarized by Paxton and Feltz, is the sentiment that the only method of evaluating existing concrete for potential D-Cracking is coring and confirming the lithology of the coarse aggregates as well as visual assessment of the condition of coarse aggregates at the time of coring. No non-destructive test methods are known to effectively evaluate in-situ concrete prior to the immergence of D-Cracks.

It is anticipated that Stage II, the Field Study, of this program will commence immediately. Designated sample areas will be selected and surveyed to document concrete performance. Information will be collected from these areas relating the highway design, with regard to the type of base materials, and with regard to the moisture tables existing in the area of the designated surveys. Types of aggregates used for the concrete production in these areas will also be collected as they are available. These samples will then be surveyed for petrographics and for selected aggregate tests. Selected pavement sections will be cored to correlate existing condition with the aggregate surveys.

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